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NORTH AMERICA

Effective GCC/Clang optimizations for Embedded systems

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Agenda

- Introduction
- Tools
- Compiler Optimization Switches
- Data types
- Variables and Functions
- Optimization Tips
- Summary

Tools

- Tools
  - Know your compiler toolchain
    - GCC based, Clang bases, Other Vendors ..
  - Read through compiler has to offer
    - Each one has few difference that could matter

Tools

- Understand the memory layout
  - Explicit Linker scripts
    - Common in bare-metal applications
  - Default linker scripts
    - Commonly used in hosted applications

Tools

- Linker map files (-Wl,-Map,mymap.map)
- Objdump – Disassemble Objects
- Size – Elf size dumper
- Readelf – Display Content of ELF files
- Nm – ELF symbol lister
- Strip – Remove Symbols and debug info
- More …

Optimization Options

- O<n> Switches
  - O0
    - -No optimizations
  - O/O1
    - Somewhere between -O0 and -O2
  - O2
    - Moderate level of optimization which enables most optimizations
  - Os
    - Like -O2 with extra optimizations to reduce code size
  - Og
    - Like -O1, better debuggability
  - Oz
    - Like -Os (and thus -O2), but reduces code size further.
  - O3
    - Like -O2, except that it enables optimizations that take longer to perform or that may generate larger code (in an attempt to make the program run faster
  - Ofast
    - Like O3 with more aggressive optimization (may violate standards compliance)

Optimization Options

- GCC
  - https://gcc.gnu.org/onlinedocs/gcc/Optimize-Options.html
- Clang doesn’t have such a page

Optimization Options

- Security
  - -fstack-protector-strong
  - -D_FORTIFY_SOURCE=2
  - -Wformat -Wformat-security
  - -Werror=format-security

Compiler Optimizations

Does Compiler support –O4 ?

Data Types

- Know processor and word-size
  - Use data-types representable in processor word size
  - Smaller datatypes
    - Code size increase
  - Larger datatypes
    - Might degrade performance
  - Also depends on processing architecture
    - X86 might work fine, but ARM may exhibit above or vice-versa

Data Types

- Delegate to compiler
  - C99 provides
    - Fixed width – uint*_t
    - Minimum width – uint_least*_t
    - Fastest width – uint_fast*_t
  - Portable datatypes
    - uint<size>_t

Variables and Functions

- Using “const”
  - is a big hint to compiler
  - Immutable data
  - Documentation
  - Better diagnostics from compiler
  - Better optimization opportunity

Variables and Functions

- Function Parameter
  - Know the ABI and calling convention
    - Depends on processor architecture
  - ARM
    - 4 registers available for parameter passing
    - -mfloat-abi
      - Hard
      - Soft
      - Softvfp
  - Know alignment
    - Set parameters sequence such that no padding is needed

Variables and Functions

- Avoid global and static data in loops
- Use `volatile` when really needed
- Avoid function calls in loops

Variables and functions

- Compiler attributes
  - Clang
  - https://clang.llvm.org/docs/AttributeReference.html
  - GCC
    - https://gcc.gnu.org/onlinedocs/gcc/Function-Attributes.html
    - https://gcc.gnu.org/onlinedocs/gcc/Variable-Attributes.html#Variable-Attributes

Optimization Tips

- Create baselines
  - Accounts for Law of diminishing returns
  - Set an End goal
- You are as good as your tools
  - Find good measurement tools
  - Augment compilation with other tools
- Dare to Experiment
  - Dig deeper into generated code

Optimization Tips

- Consider Portability
  - Follow ISO C standards and demand it from compiler (–std=c99)
  - Its easy to give-up portability under stress
  - Use predefined compiler preprocessor macros
    - https://sourceforge.net/p/predef/wiki/Compilers/

#pragma GCC optimize (“unroll-loops”)

Optimization Tips

- Which one is better ?

```
x = x ? 0:10
```

```
if (x) {
  x = 0;
} else {
  x = 10;
}
```

Optimization Tips - Stack

- Know default stack size – Its not unlimited
- Local variables e.g. Large arrays
- Take a hard look at recursive functions
- End-call optimization

```
int foo()
{
   ...

   if (..)
     return bar();
   else
     return 0;
}
```

Optimization Tips

- Put most likely code in hotpath
  - Cascade of if-then-else
  - Look for converting simple conditions to switch-case
- Help tail recursion Elimination
  - Return value of recursive call without modifications

Optimization Tips

```
int factorial(int x)
{
  if (x == 0) {
    return 1;
  } else {
    return x * factorial(x - 1);
  }
}
```

Return value is processed

```
int factorial(int x, int f)
{
  if (x == 0) {
    return f;
  } else {
    return factorial(x - 1, f * n);
  }
}
```

Return value is not processed

Summary

Help the compiler and it will help you

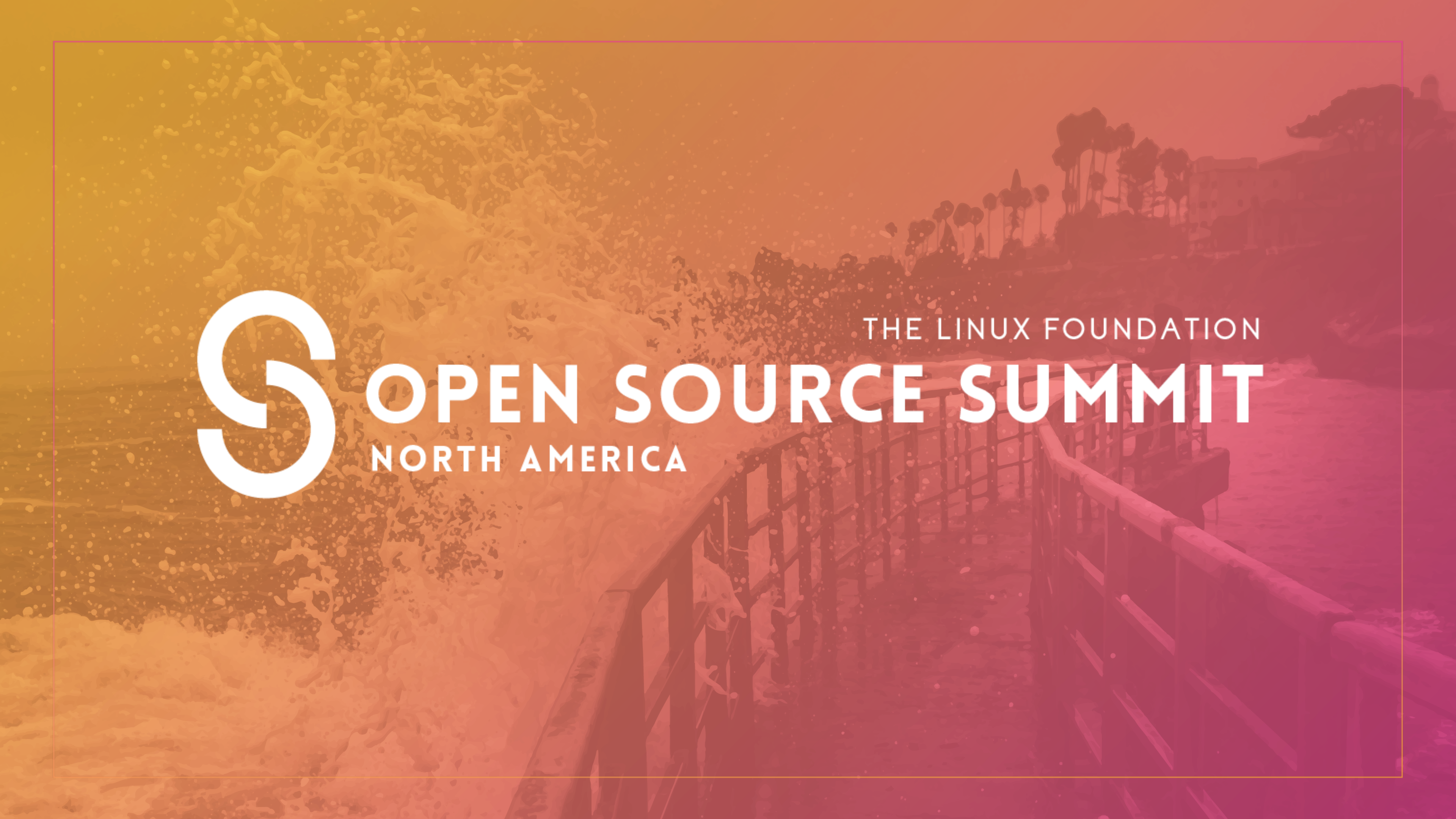
Summary

- Compiler has to be conservative
  - It wont apply an optimization if its not sure
    - Pointer aliasing
  - Do-while is better than for-loops
    - Loop termination test can be optimized out
  - Use compiler provided annotations
    - Function and variable attributes
    - Pragmas
  - Use intrinsic where possible

Summary

- Recommendations
  - Avoid “Release” and “Debug” modes
    - Uniform optimization across production and development saves a lot of time
  - Know your system
    - Processor architecture, bus width, DRAM, Flash, clock speeds etc.
  - Profile before optimize
  - Delegate to tools as much as possible
    - Don’t make them do things they can’t do well
  - Avoid inline assembly
  - Make portability as priority

Thank you



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